Sun River Watershed Water Quality Monitoring Oversight & Analysis Project – 2006

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Final Report

Background

The Sun River, located in north central Montana, is a major tributary of the Missouri River. The watershed consists of 1.4 million acres and drains 2,200 square miles of the east slope of the Rocky Mountains. The watershed contains the U.S. Department of the Interior Bureau of Reclamation's Sun River Project, which is comprised of two irrigation districts, the Greenfield's Irrigation District (GID) and Fort Shaw Irrigation District. Collectively the districts irrigate 96,000 acres within the Sun River watershed. Irrigation water for these two projects is sourced from Sun River. Major land uses in the Sun River watershed include livestock grazing, crop production, forestlands, urban and rural residential, and wildlife habitat. The Sun River watershed contains approximately 100,000 acres of irrigated lands, 300,000 acres of dry cropland, 400,000 acres of rangeland, and 100,000 acres of pastures.

The Montana 1996 and 2000 303(d) list (MT-DEQ) for the Sun River planning area includes the entire Sun River, Muddy Creek, lower Ford Creek, Gibson Reservoir, Willow Creek Reservoir and Freezout Lake. Impairments identified and included in documentation of the 303(d) list are: sediment, nutrients, thermal modification, organic enrichment/DO, pH, salinity/TDS/chlorides, habitat alteration, and flow alteration. Probable causes for these impairments are agriculture and hydromodification. The identified impairments cause water bodies to only partially support beneficial uses of fisheries, aquatic life, swimming, and recreation. Portions of Sun River and its tributaries are also non-supporting of some beneficial uses.

In 2004, the Sun River Watershed Group contracted Montana State University Extension Water Quality (MSUEWQ) to perform water quality sampling, data compilation, and analysis at 24 sites within the Sun River Watershed. The 2004 report recommended continued monitoring, with some modified sampling, and monitoring of several new sites. MSUEWQ continued monitoring water quality within the watershed in 2005. Results from the 2004 and 2005 studies defined current conditions within the watershed and helped to refine the monitoring program. The 2005 study recommended a significantly scaled back monitoring program in 2006. This scaled back program would continue monitoring at key sites within the watershed with intentions that the scaled back monitoring program would serve to detect any significant changes within the watershed while keeping monitoring costs at a minimum.

A scaled-back monitoring program was instituted in 2006. This report summarizes the findings and outcomes of the 2006 monitoring effort.

Approach

Recommendations from the 2005 study that were incorporated into the 2006 monitoring plan were: 1) a reduction in number of sampling sites, 2) a change in the frequency of sampling, and 3) a reduction in the number of water quality parameters for which analyses would be completed on collected water quality samples.

Water quality and flow data were collected from five sites within Sun River watershed in 2006 by the Sun River High School Science Club (SRHSSC) and MSUEWQ staff. Water quality samples were collected at two sites on Sun River – Great Falls and Augusta, and from three tributaries to Sun River - Mill Coulee, Adobe Creek, and Big Coulee. Additionally the United States Geological Survey (USGS) monitored one site on Sun River (USGS station #06089000 – Sun River near Vaughn) and one site on Muddy Creek (USGS station #06088500 – Muddy Creek at Vaughn). The Sun River at Augusta monitoring station was continued in 2006 as it is located in the upper portion of the watershed and allows for characterization of the quality of baseflow water in Sun River and which enters the agricultural/irrigation region of Sun River watershed. Conversely, the Sun River at Great Falls monitoring station was maintained in 2006, in as much as water passing this monitoring station represents the water quality exiting the watershed and that would be contributed to Missouri River. Mill Coulee, Muddy Creek, Adobe Creek, and Big Coulee were also monitored in 2006; these tributaries were found in previous studies to be principal sources of water quality impairments to Sun River. Figure 1 shows the locations of these monitoring sites.

At each of these five sites sampled by the SRHSSC and MSUEWQ, the following parameters were measured onsite: salinity (measured as specific conductance), water temperature, dissolved oxygen, conductivity, pH, and turbidity. These on-site measurements, with exception of turbidity, were made using the Horiba meter. Turbidity was measured using a Hach turbidity meter, which reported values in nephelometric turbidity units (NTUs). Additionally, water samples were collected and sent to Energy Laboratories in Helena, MT for analysis for nitrate + nitrite nitrogen, total kjeldahl nitrogen, total phosphorus, and total suspended sediment. Chain of custody procedures were followed, as described in Section 14.0 (Sample Handling and Custody Requirements) of the MT Department of Environmental Quality's Non-Point Source Water Quality and Standard Operating Procedures (MT DEQ, 1995). Two sites monitored by USGS recorded flow, pH, conductivity, temperature, ammonia nitrogen, nitrate + nitrite nitrogen, nitrite nitrogen, total nitrogen, orthophosphate, phosphorus, selenium, and suspended sediment.

Excluding USGS sites, there were four sampling events in 2006. Sites were sampled in April, May, June, and October. It was thought that sampling sites four times would show trends and allow for any changes in water quality to be detected, while

limited sampling and analyses would reduce costs significantly compared to monthly sampling in the summer, as was the case in previous years. Sites were sampled in May and June, when flows are usually elevated (due either to spring runoff or irrigation diversions and releases), and April and October when flows would likely be lower – and more representative of baseflow conditions. Most of the sampling was completed by the SRHSSC, which sampled the five sites in April, May, and June. MSUEWQ staff completed the October sampling event. The USGS stations were sampled more often, as per the agency's protocol. Efforts were made by the two sampling entities to collect water quality samples within the same time frame during months when both groups sampled.

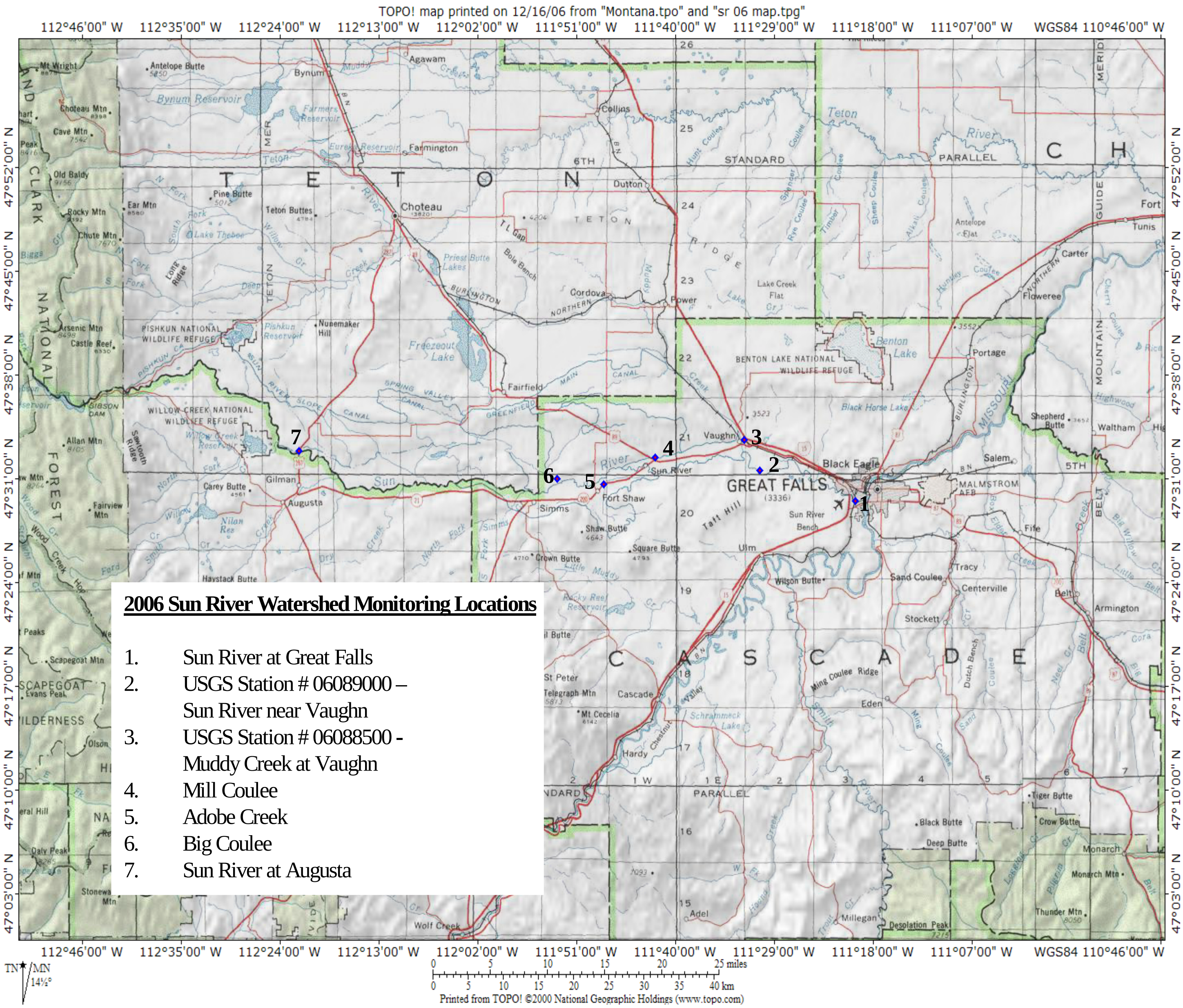

Figure 1. Sun River watershed sampling locations, 2006.

Water Quality Status – 2006

Nitrogen

Excessive nitrogen levels, when in the presence of available phosphorus, can result in eutrophication. Three types of measurements were made in 2006 to assess nitrogen presence and concentrations within Sun River Watershed – total kjeldahl nitrogen (TKN), nitrate + nitrite – N, and total nitrogen (TN). Table 1 show statistics for nitrate + nitrite – N concentrations, measured at all stations. Concentrations were least in upper Sun River at the Augusta monitoring site, where all measured nitrate + nitrite-N concentrations were less than the reporting limit of 0.01 mg/L. The highest nitrate + nitrite - N concentrations were measured in samples collected from Muddy Creek at Vaughn and from Mill Coulee. All nitrate + nitrite N concentrations were less than 10 mg/L concentration, the human health standard for nitrate + nitrite nitrogen in drinking water sources. Concentrations measured in 2006 were within the same range as concentrations measured in samples collected in 2005.

Table 1. Nitrate + Nitrite – N concentration (mg/L), Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR[1/] @ Great Falls	0.50	0.07	0.96
SR near Vaughn	0.49	0.05	0.94
Muddy Creek at Vaughn	1.9	0.39	3.33
Mill Coulee	1.3	0.52	2.51
Adobe Creek	0.26	0.04	0.79
Big Coulee	0.71	0.15	1.53
SR @ Augusta	<0.01	<0.01	<0.01

[1/]SR = Sun River

Samples collected by the SRHSSC and MSUEWQ were analyzed for TKN. Total kjeldahl nitrogen (TKN) analysis is a measure of both ammonia form nitrogen and nitrogen present in organic material (suspended particulate, algae) in water. In the absence of ammonia, TKN provides a measure of organic-sourced nitrogen. Table 2 shows TKN values measured in 2006. USGS did not report TKN for their samples, but did report total nitrogen. By subtracting total nitrogen from nitrate + nitrite, we were able to calculate TKN values for those stations, assuming absence of ammonia. Highest concentrations of organic nitrogen were measured in samples from Adobe Creek and Big Coulee. There are no standards or targets specifically for TKN in Montana water systems and supplies. Concentrations measured in 2006 are within the same range of concentrations measured in samples analyzed in the past.

Table 2. TKN concentration (mg/L), Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR @ Great Falls	0.6	0.4	0.9
SR near Vaughn[2/]	0.3	0.19	0.46
Muddy Creek at Vaughn[2/]	0.44	0.04	1.03
Mill Coulee	0.73	0.4	1.1
Adobe Creek	0.88	0.8	0.9
Big Coulee	0.88	0.6	1.1
SR @ Augusta	0.3	0.2	0.5

[2/] = TKN values for these USGS monitoring stations were calculated based on reported TN and N+N-N values.

The total nitrogen target in Upper Sun River is set at 350 ug/L (0.35 mg/L), while the target is set at 650 ug/L (0.65 mg/L) in Lower Sun and Muddy Creek. Table 3 shows the range of total nitrogen concentrations for samples collected in 2006. In the upper Sun River, which is Sun River above the confluence with Muddy Creek, only samples collected at the Augusta monitoring station meet the target of 0.35 mg/L. In lower Sun River and Muddy Creek, only one sample, which was collected at the Great Falls station, was below the 0.65 mg/L threshold. Three samples collected at SR near Vaughn station had total nitrogen concentrations below this 0.65 mg/L threshold, and all of the samples collected from Muddy Creek had total nitrogen concentrations exceeding the 0.65 threshold. Although thresholds/targets are exceeded, total nitrogen concentrations measured in 2006 are similar to total concentrations measured in 2005.

Table 3. Total nitrogen concentration (mg/L), Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR @ Great Falls	1.07	0.6	1.36
SR near Vaughn	0.81	0.49	1.23
Muddy Creek at Vaughn	2.36	1.09	3.76
Mill Coulee	2.05	1.5	2.91
Adobe Creek	1.11	0.9	1.69
Big Coulee	1.58	1.2	2.33
SR @ Augusta	0.3	<0.5	0.5

Total Phosphorus

Excessive levels of phosphorus in streams and lakes can stimulate growth of aquatic plants and other organisms, and, like nitrogen, can exacerbate eutrophication. Phosphorus is generally strongly adsorbed to soil particles. Phosphorus can be transported into surface water with suspended sediment sourced from runoff water from agricultural fields; phosphorus can also attach to organic debris and livestock waste eroded into surface water. Table 4 lists total phosphorus concentrations measured in water samples collected during 2006 monitoring. The Sun River TMDL sets a target phosphorus concentration of 0.05 mg/L for Lower Sun River and Muddy Creek and a target of 0.039 mg/L for Upper Sun River. Average concentrations in lower Sun River

meet the target, yet concentrations in Muddy Creek exceed 0.05 mg/L. Muddy Creek has the highest phosphorus concentrations of all the stations measured. In upper Sun River, the 0.039 mg/L target is met only at the Augusta station during all sampling events. Mill Coulee, Adobe Creek, and Big Coulee meet the target during some, but not during all of the sampling events. Total phosphorus concentrations are within the same range of concentrations reported in 2005.

Table 4. Total Phosphorus concentration (mg/L), Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR @ Great Falls	0.036	0.015	0.069
SR near Vaughn	0.049	0.011	0.164
Muddy Creek at Vaughn	0.146	0.019	0.48
Mill Coulee	0.055	0.001	0.168
Adobe Creek	0.064	0.006	0.132
Big Coulee	0.039	0.015	0.075
SR @ Augusta	0.006	0.001	0.01

Conductivity (specific conductance)

Conductivity is a measure of the ability of water to pass an electric current. Conductivity increases with the number of ions in water, and thus conductivity indicates presence of dissolved substances. These substances include both naturally occurring minerals and contaminants. Conductivity is an important measurement in as much as it has an influence on aquatic biota and is an issue when water is used for irrigation purposes. Salinity also affects in-stream biological uses.

To protect agricultural uses, the Sun River TMDL sets 1.0 mS/cm as the in-stream salinity target from April 30 – September 30. The TMDL sets a target of 1.4 mS/cm for all other times of the year. Table 5 presents average, minimum, and maximum conductivity values measured at sampling sites within the Sun River monitoring project in 2006. Conductivities of all samples collected from the Sun River in 2006 were below the targets. Big Coulee was the only site measured that had conductivity values averaging greater than 1 mS/cm. With exception of one sample collected from Big Coulee in August, all samples collected from Big Coulee had conductivities exceeding the target conductivity. In Muddy Creek, conductivities were measured before, after, and during the April – September period. Only one value, that for a sample collected from the Muddy Creek at Vaughn monitoring site, exceeded 1 mS/cm during the April 30 – September 30 monitoring period. Conductivity values greater than 1 mS/cm were measured only outside the April 30 – September 30 monitoring period in Mill Coulee. The greatest conductivity measurement occurred in Adobe Creek. This value was measured on October 25th; none of the other conductivities measured for samples from this site were greater than 1 mS/cm. Conductivity values measured in 2006 were very similar to values measured in 2005 and were within the same range of values measured before 2005.

Table 5. Conductivity (mS/cm, numerically equivalent to mmhos/cm), Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR @ Great Falls	0.61	0.26	0.79
SR near Vaughn	0.66	0.29	0.79
Muddy Creek at Vaughn	0.92	0.45	1.49
Mill Coulee	0.91	0.66	1.58
Adobe Creek	0.99	0.47	2.97
Big Coulee	1.36	0.79	2.30
SR @ Augusta	0.33	0.22	0.41

pH

The pH of water is an indicator of acidity and alkalinity of water, which affect biological availability and solubility of chemical constituents in water. While geology controls baseline pH in a stream, water temperature and seasonal and daily changes in photosynthesis are the greatest causes of variation in pH. Photosynthesis is a function of chlorophyll containing vegetation, including macrophytes, algae, and plankton.

The acceptable range for pH in surface water, according to Montana's standards is 6.5 to 9. Table 6 shows pH values recorded for samples collected as part of the Sun River monitoring project in 2006. Table 6 shows that most pH measurements fell within the 6.5 to 9 range. At four of the stations maximum pH values were greater than 9. All 2005 samples taken at these stations were within the acceptable range, so 2006 measurements were slightly greater than measurements taken last year.

Table 6. pH, Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR @ Great Falls	8.75	7.91	9.38
SR near Vaughn	8.53	8.30	8.60
Muddy Creek at Vaughn	8.58	8.4	8.80
Mill Coulee	8.79	7.97	9.27
Adobe Creek	8.82	7.71	9.5
Big Coulee	8.96	7.94	9.46
SR @ Augusta	8.68	8.10	8.87

Sediment

Three different types of measurements were made to assess sediment concentrations. Sun River Science Club and MSUEWQ collected samples that were analyzed by Energy Labs, Helena, MT, for total suspended solid (TSS). TSS are solids that will not pass through a 50 micron filter. TSS is made up of organic and mineral particles that are transported in the water column. TSS is closely linked to erosion within the river channel, bottom and bank scour, and erosion/sediment transport from land surfaces. High TSS levels can be detrimental to aquatic ecosystems, as high sediment concentrations and siltation can cause issues for fish and can limit light penetration,

which limits ability of aquatic plants and algae to produce food and oxygen for other aquatic organisms.

SRHSSC and MSUEWQ personnel completed 'on site' turbidity measurements at the same time water samples were collected for analyses. Turbidity is a measure of water clarity. A turbidity measurement quantifies the degree to which light traveling through water is dispersed by suspended particles present. Not only does high turbidity affect aesthetic appeal of waters, turbidity also has the same effects on water quality as suspended sediment. Turbidity is characterized by a measure of nephelometric turbidity units (NTU). The greater the turbidity, the greater the NTU number. Previous studies within Sun River watershed have found a good linear correlation between turbidity and TSS. The 2005 data netted an R^2 of 0.97 for the relationship between turbidity and TSS. Using all available data for the Sun River watershed, the calculated R^2 for this same relationship was determined to be 0.71. Both turbidity and TSS were only collected during two of the four sampling events in 2006. As expected, when 2006 TSS measurements from Energy Lab were graphed as a function of 'on-site' turbidity measurements, a well-defined linear relationship became apparent; the correlation coefficient for the 2006 data set was determined to be R^2 of 0.92 (Figure 2). Subsequently, this relationship was used to predict TSS concentrations for the other two sampling events, where only turbidity was measured.

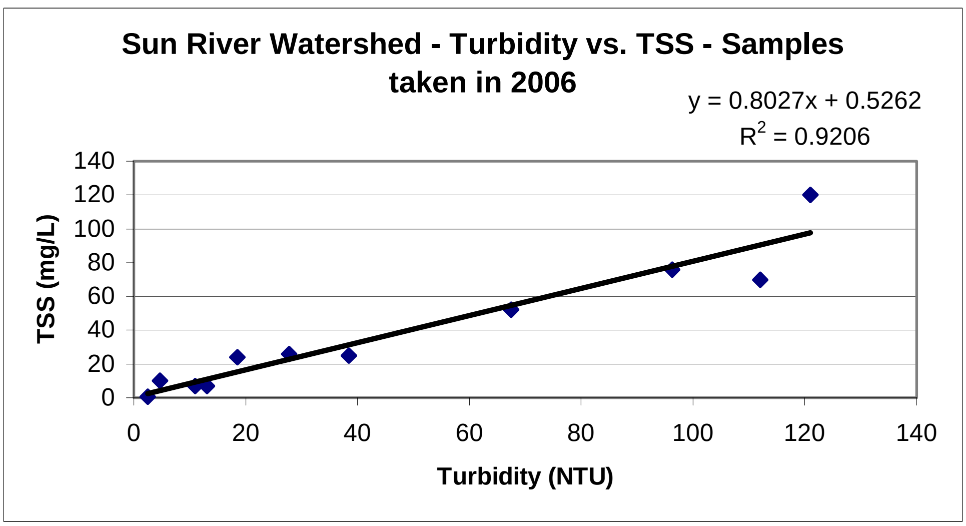

Figure 2. Turbidity and TSS correlation – 2006.

The Sun River TMDL sets a target for TSS concentrations in the upper Sun River. TSS concentrations are to be less than 10 mg/L at discharges under 200 cfs. Table 7 presents TSS, either measured on samples submitted to Energy Labs or estimated from turbidity data collected during the 2006 Sun River monitoring project. Excluding SR at Great Falls monitoring station, which would be classified as lower Sun River, only TSS values measured at Sun River at Augusta are within the target. In as much as flow did not exceed 200 cfs during the sampling events, the 10 mg/L target would apply. Only

three of the samples measured in the tributaries were not greater than 10 mg/l. These results are within the same range as results from 2005.

Table 7. Total suspended sediment concentration (TSS), either measured on samples submitted to Energy Lab or estimated from measurements of turbidity 'on site', Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR @ Great Falls	36 [3/]	7	76
Mill Coulee	28 [3/]	6 [3/]	52
Adobe Creek	46 [3/]	7 [3/]	120
Big Coulee	34 [3/]	14 [3/]	70
SR @ Augusta	3 [3/]	<1	7

[3/] = Values estimated based on turbidity measurements. All average concentrations are based on both actual measurements and estimated values from turbidity.

USGS collected suspended sediment concentration (SSC) data at two sites they monitored, which are included within this report. Table 8 presents those results. High SSC within a stream has potentially the same consequence as high TSS concentration and turbidity. The difference between SSC and TSS is a function of how a water sample is analyzed for sediment. TSS determinations are made using an aliquot of the water sample, while determination of SSC involves use of the entire sediment mass contained within the sample, which might include sand-sized particles that easily and quickly settle out of solution. Sand and silt-sized particles generally would not be included in the determination of TSS. Thus, TSS concentrations tend to be less than SSC concentrations and a good relationship between these parameters hasn't been established. SSC can be significantly affected by streamflow velocity. In lower Sun River, the TMDL sets targets for SSC instead of TSS. One recommendation of the 2005 report was that SSC be monitored at all Lower Sun River monitoring stations. We were unable to implement this recommendation as Energy Laboratories, the lab used to analyze water quality samples, did not have a process in place in 2006 to measure SSC. In the lower Sun River below Muddy Creek, the target SSC was set to be less than 42 mg/L. At Sun River near Vaughn, four of the eight samples collected had SSC less than 42 mg/L. This is very similar to results from 2005. The TMDL also set a target SSC for Muddy Creek of 29,959 tons per year. The limited data analyzed within this report do not allow for calculations to be made to determine whether this target was met.

Table 8. Suspended sediment concentration (SSC, mg/L), measured on samples collected by USGS, Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR near Vaughn	63	24	245
Muddy Creek at Vaughn	157	35	523

Dissolved Oxygen (DO)

DO concentration indicates how well aerated the water is (presence of oxygen). Low DO levels cause biological stress in aquatic organisms. Ability of water to maintain

acceptable DO levels is dependent on temperature, time of day, season, turbidity, and salinity. DO is measured "in stream". A target minimum level of 5 mg/L DO is set to protect early life stages in lower Sun River and Muddy Creek. The TMDL sets a minimum of 8 mg/L DO for early life stages in Upper Sun River. DO was not measured at the two USGS stations. At stations monitored by the SRHSSC and MSUEWQ, DO was only measured three times due to equipment problems. Table 9 presents DO measurements. All dissolved oxygen concentration measurements were greater than the 8 mg/L target. DO levels were slightly higher than 2005 measurements of DO.

Table 9. Dissolved oxygen concentration (mg/L), measured 'in stream', Sun River watershed monitoring project, 2006.

Station	Average	Min	Max
SR @ Great Falls	8.5	8.3	8.7
Mill Coulee	9.9	8.7	12.5
Adobe Creek	9.4	8.2	11.2
Big Coulee	10.6	8.7	12.5
SR @ Augusta	11.0	10.2	12.4

Summary and Conclusions

As a continuation of previous water quality monitoring efforts in Sun River watershed, a scaled back water quality monitoring program was implemented within Sun River watershed in 2006. Water quality was monitored and/or samples were collected for laboratory analyses from five sites four times during the 2006 open-water period. Additionally, USGS monitored several stations within the watershed. Data were organized, analyzed, compared to targets set in the TMDL, and compared to concentrations measured in 2005.

With the exception of the Sun River at Augusta monitoring station, all monitoring sites had some concentrations during the monitoring period that exceeded total nitrogen targets set in the TMDL. Mill Coulee, Adobe Creek, Big Coulee, and Muddy Creek only met the total phosphorous target during some of the sampling events. With exception of one sample collected from Big Coulee in August, all samples collected from Big Coulee had conductivities exceeding the target set in the TMDL. Adobe Creek, Mill Coulee, and Muddy Creek all had one conductivity measurement that exceeded TMDL targets. TSS targets were exceeded in some of the samples measured at Adobe Creek, Big Coulee, Adobe Creek, and Mill Coulee. Additionally half of the results from the SR near Vaughn station indicated exceedence of SSC targets.

Water quality data collected in 2006 was very similar and within the same range of values measured in 2005. As in years past, turbidity again correlated very well with TSS. No significant changes in water quality were detected in 2006.

It would be beneficial and it is recommended that the monitoring program implemented in 2006 be continued through at least 2007. Continual monitoring in some

format is key to ensuring that water quality does not deteriorate and to document improvements within the watershed. In the event that revised management practices are put into place or significant changes in land use practices evolve, the monitoring plan should be reviewed and revised accordingly.

References

Montana Dept. of Environmental Quality (MDEQ). 1995. Historical NonPoint Source Water Quality and Standard Operating Procedures. Available online at http://www.deq.state.mt.us/wqinfo/monitoring/SOP/sop.asp (verified Mar. 1 2007).